Original Article

Enamel Surface Roughness after Debonding of Orthodontic Brackets and Various Clean-Up Techniques

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Abstract

Objective: This study aimed to evaluate enamel roughness after adhesive removal using different burs and an Er:YAG laser.

Materials and Methods: The buccal surfaces of forty human premolars were sealed by two layers of nail varnish, except for a circular area of 3 mm in diameter on the middle third. The enamel surfaces were initially subjected to profilometry analysis and four parameters of surface irregularity (Ra, Rq, Rt and Rz) were recorded. Following bracket bonding and debonding, adhesive remnants were removed by tungsten carbide burs in low- or high- speed handpieces (group 1 and 2, respectively), an ultrafine diamond bur (group 3) or an Er:YAG laser (250 mJ, long pulse, 4 Hz) (group 4), and surface roughness parameters were measured again. Then, the buccal surfaces were polished and the third profilometry measurements were performed.

Results: The specimens that were cleaned with a low speed tungsten carbide bur showed no significant difference in surface irregularity between the different treatment stages ($p>0.05$). Surface roughness increased significantly after clean-up with the diamond bur and the Er:YAG laser ($p<0.01$). In comparison between groups, adhesive removal with tungsten carbide burs at slow- or high-speed handpieces produced the lowest, while enamel clean-up with the Er:YAG laser caused the highest values of roughness measurements ($P<0.05$).

Conclusion: Under the study conditions, application of the ultrafine diamond bur or the Er:YAG laser caused irreversible enamel damage on tooth surface, and thus these methods could not be recommended for removing adhesive remnants after debonding of orthodontic brackets.

Key Words: Laser, Solid-state; Dental Debonding; Enamel; Orthodontics

Journal of Dentistry, Tehran University of Medical Sciences, Tehran, Iran (2013; Vol. 10, No.1)

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Received: 17 September 2012
Accepted: 5 December 2012

INTRODUCTION

Debonding aims to remove orthodontic attachments and all remaining adhesives from the tooth and to restore the surface to its pre-treatment state as much as possible [1]. Mechanical removal of remaining composite after debonding has been shown to be detrimental for enamel surface, causing a significant amount of enamel loss [2-5] and irreversible enamel damage [6-9]. The presence of prominent areas or grooves on the tooth surface can contribute to enamel staining and plaque accumulation which in turn may cause esthetic concerns and enamel demineralization. Although the occurrence of scarring on the enamel surface after adhesive removal appears to be inevitable, the damage can be reduced to a negligible level if selecting a proper technique. So far, different modalities have been used to remove adhesive remnants after debonding including hand instruments (pliers and scalers), various burs, Soflex discs, ultrasonic devices and air abrasion units. Tungsten carbide burs used in low [8, 10] or high [11] speed handpieces have been frequently shown to produce the most satisfactory results, but some studies found that they are more damaging than a green rubber wheel [6], an innovative a finishing carbide bur [12] or a fiber-reinforced composite bur [13] for tooth enamel. The use of diamond finishing burs for composite removal is also popular among some dentists because of their relatively weak abrasive potential. However, these burs can cause irreversible enamel damage [6, 8, 14], which may be due to the shape of the bur or its sharpness [15]. Another technology that can be used for composite removal is laser. In orthodontics, lasers have been investigated for their efficacy in enamel etching [16, 17], increasing enamel resistance to caries [18, 19], reconditioning of metallic or ceramic brackets [20, 21], enhancing tooth movement [22, 23] and pain relief [24, 25]. A Great attempt has also been made to use this technology for selectively removing restorative materials without damaging the tooth structure. Although different laser wavelengths have been used experimentally for enamel clean-up [26-28], it is well clear that erbium family lasers are more suited for this purpose. The application of Er:YAG (erbium: yttrium-aluminum-garnet) laser in removing restorative materials from cavity walls has been investigated in previous studies [29-31]. However, the data are limited regarding the use of erbium lasers in cleaning the enamel surface after bracket removal. Using SEM images, Almedia et al. [32] found that the Er:YAG laser performed significantly better than the conventional technique in removing composite remnants after debonding of orthodontic brackets, although it produced a significantly higher amount of enamel loss compared to that observed in the tungsten-carbide bur group. Evaluating the effects of different instruments on enamel surface have been commonly performed qualitatively using scanning electron microscope (SEM) or stereomicroscope images to describe the surface topography. However, employing quantitative scales for this purpose allows for better comparison of the damage caused by different instruments, thus enhancing selection of a more efficient, but less hazardous one for enamel clean-up. The aim of this study was to evaluate the efficacy of an Er:YAG laser compared to different rotary burs in removing adhesive remnants after debonding of orthodontic brackets.

MATERIALS AND METHODS

The sample consisted of 40 maxillary first or second premolars removed because of orthodontic purposes. The selected teeth were intact and without any caries, cracks or hypoplasia on the enamel surface. The teeth were cleaned from soft tissue remnants and the roots were cut off approximately 2 mm below the cemen-to-enamel junction. The crowns were embedded in self-curing acrylic resin using moulds of 25 mm in diameter and 20 mm in height, in such a way that the buccal surface of the tooth would be oriented horizontally and about 1-2 mm above the rim of the mould. The mounted teeth were randomly divided into four experimental groups of 10 and a number was assigned to each specimen. The blocks were kept in distilled water at room temperature during the time of the experiment in order to

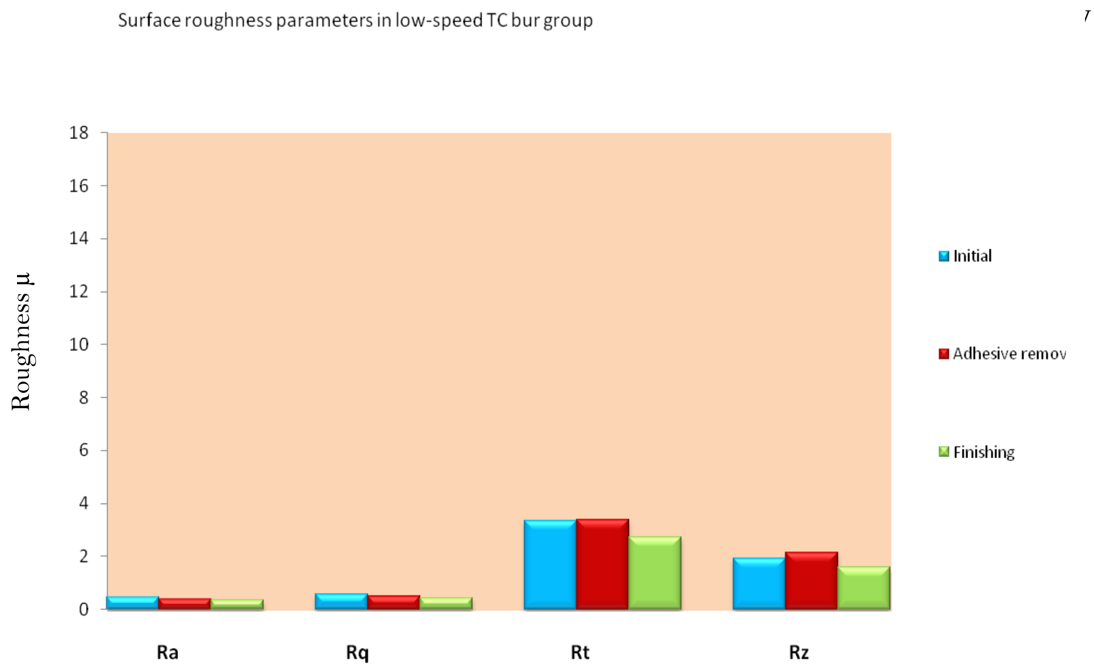

Fig 1. Surface roughness parameters of the low speed TC bur group at different treatment stages.

prevent dehydration.The buccal surface of each tooth was covered by two layers of nail varnish, keeping a circular area of 3 mm in diameter on the middle part exposed to provide the same area of measurement in different treatment stages. Before bonding, the surface profile was analyzed at the center of the exposed area using a contact prophylometer (Talysurf 120 L; Rank Taylor Hobson, Leicester, England) with a stylus tip oriented perpendicular to the enamel surface during scanning (initial stage).

The analysis was performed with a cut off of 0.25 mm and a maximum length of 1.2 mm, recording four roughness parameters as follows:

1-Ra (arithmetic mean value of surface roughness): Ra indicates the average roughness and is defined as the arithmetic mean deviation of the surface valleys and peaks from the center line in the measuring length.

2-Rq (root mean square roughness): Rq is the root mean square deviation of the assessed

3-Rt (maximum roughness height): Rt is the maximum peak-to-valley height over the sampling length.

6-Rz (mean roughness depth): Rz is the mean vertical distance between the highest peak and the deepest valley of five adjacent measuring sections.

The measurements were made twice for each specimen and the mean value was recorded.

After the first surface roughness measurement, the buccal surfaces were etched with 37% orthophosphoric acid gel for 30 seconds, rinsed thoroughly with water and dried with compressed air.

Transbond XT primer (Monrovia, CA, USA, 3M Unite) was coated on the enamel surface. Then, a layer of vaseline was applied on the bonding pad of a stainless steel standard edgewise second premolar bracket (Dentaurum, Ispringen, Germany) to prevent composite adhesion to the bracket base; consequently, leaving the complete adhesive on the enamel surface.

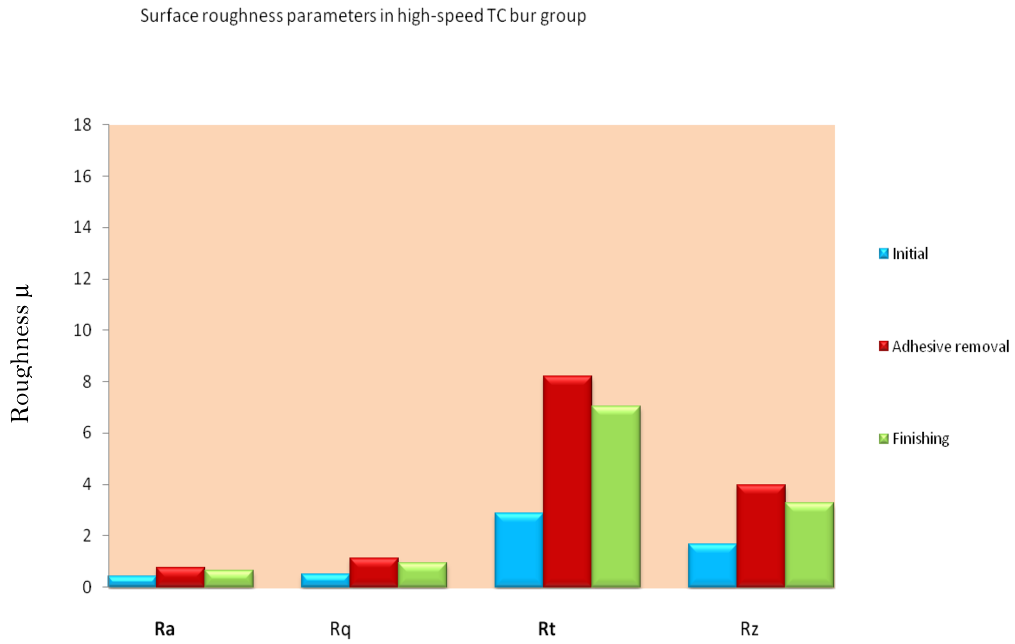

Fig 2. Surface roughness parameters of the high speed TC bur group at different treatment stages

A sufficient amount of adhesive was later placed on the base and the bracket was pressed in the middle of the exposed area. The excess adhesive was removed with a dental explorer and each tooth was cured for a total of 40 seconds from occlusal, gingival, mesial and distal directions (10 seconds each). Curing was performed with Bluephase C8 (Ivoclar Vivadent, Schaan, Liechtenstein) light emitting diode (LED) using a power density of 650 mW/cm2.

Then, the bracket was removed easily using a pair of tweezers, leaving all the adhesive remained on the enamel surface. This procedure was repeated for all the specimens.

The adhesive remained after debonding was removed by using different instruments. In the first group, the adhesive was removed with a 12-fluted tungsten carbide bur (Dentaurum no. 123-604, Ispringen, Germany) operated at low speed by air cooling. A tungsten carbide bur in group 2 (SS White Burs, Inc. no. 15664-5, Lakewood, NJ, USA) and an ultrafine diamond finishing bur (SS White Burs, Inc. no. 859-016, Lakewood, NJ, USA) in group 3 were used for cleaning adhesive remnants,

Table 1. Comparison of Surface Roughness Parameters Among Study Groups in the Adhesive Removal Stage

	Ra		Rq		Rt		Rz	
	Mean±SD		**Mean±SD**		**Mean±SD**		**Mean±SD**	
Low Speed TC Bur	0.41±0.08	A	0.51±0.11	A	3.54±1.40	A	2.21±0.53	A
High Speed TC Bur	0.60±0.20	A, B	0.82±0.32	A, B	5.54±2.85	A, B	3.76±1.16	A, B
Diamond Bur	1.09±0.10	B	1.39±0.12	B	8.39±0.89	B	5.81±0.72	B
Er:YAG Laser	1.90±0.62	C	2.96±1.03	C	14.82±4.21	C	10.25±3.01	C

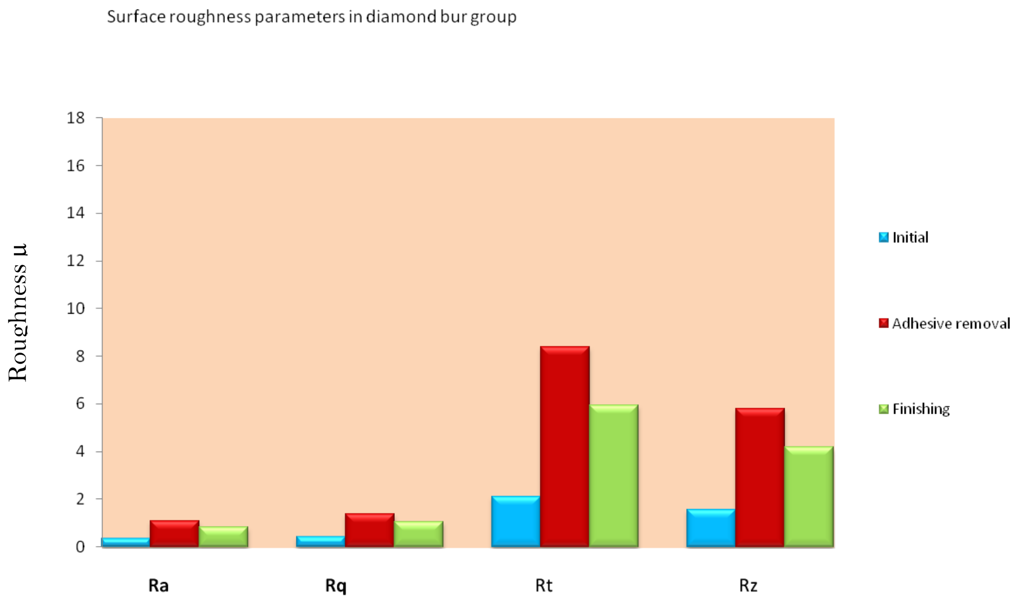

Fig 3. Surface roughness parameters of the ultrafine diamond bur group at different treatment stages.

both connected to a high speed handpiece with water cooling. In the fourth group, the composite was removed with an Er:YAG laser device (Fidelis Plus II, Fotona, Slovenia) irradiating a wavelength of 2940 nm. The laser operated with a pulse energy of 250 mJ, pulse duration of 350 µs (long pulse) and a pulse repetition rate of 4 Hz under air and water cooling.

The laser beam was directed in a focused, non-contact mode and perpendicular to the enamel surface using RO7 handpiece.

The clean up procedures in all groups were performed by the principal investigator and great care was undertaken not to damage the surrounding enamel. The process of adhesive removal was continued until no adhesive remained on visual inspection and the enamel surface felt smooth without any projection during tactile examination with a dental explorer. After adhesive removal, the surface was subjected for the second time to contact profilometry analysis and the roughness values were recorded (adhesive removal stage).

Finally, all the specimens received polishing

Table 2. Comparison of Surface Roughness Parameters Among Study Groups in the Finishing Stage

	Ra		Rq		Rt		Rz	
	Mean±SD		**Mean±SD**		**Mean±SD**		**Mean±SD**	
Low-Speed TC bur	0.35±0.16	A	0.43±0.19	A	2.76±1.25	A	1.64±0.72	A
High-Speed TC bur	0.54±0.23	A, B	0.72±0.32	A, B	5.07±2.57	A	2.98±1.23	A, B
Diamond Bur	0.83±0.18	B	1.05±0.23	B	5.93±1.40	A	4.19±1.10	B
Er:YAG Laser	1.49±0.41	C	2.35±0.75	C	11.79±3.53	B	7.51±2.15	C

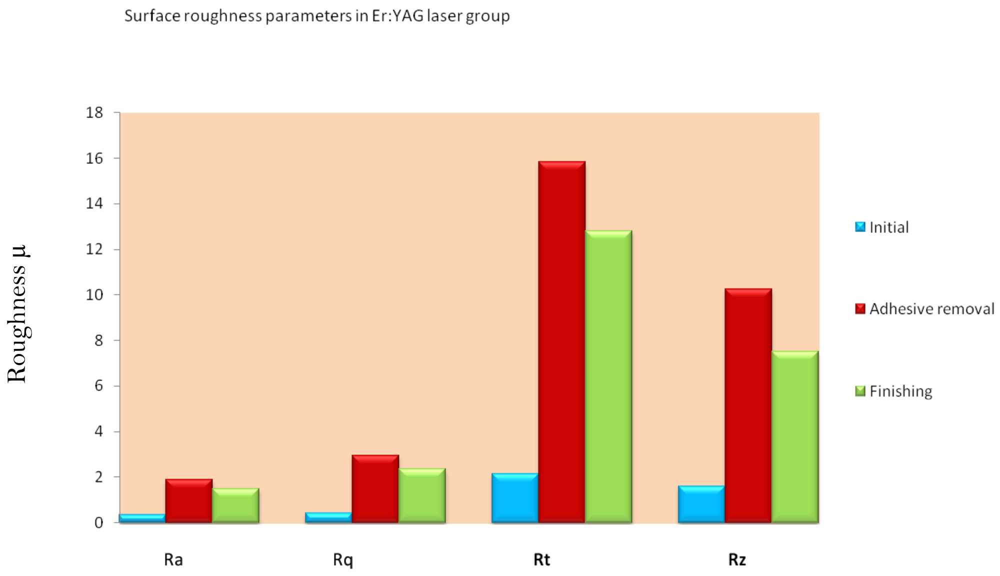

Fig 4. Surface roughness parameters of the Er:YAG laser group at different treatment stages.

with rubber prophy cups (Product Code: ORRA3360, Astek Innovations Ltd, Altrincham, United Kingdom) and water slurry of fine pumice (Patterson Dental Co., Sacramento, CA, USA) for 10 seconds, after which the third profilometry measurement was taken (finishing stage).

Statistical analysis

The normality of the data was confirmed by the Kolmogorov-Smirnov test and the homogeneity of variances by the Levene's test. The data were analyzed by a repeated measure analysis of variance through the SPSS software (Version 11.5, Chicago, Illinois, USA). The level of significance was determined at $p<0.05$.

RESULT

The repeated measure analysis of variance showed a significant interaction between the method of adhesive removal and the treatment stage ($p<0.001$).

Therefore, one way analysis of variance was performed to delineate statistical differences in surface roughness parameters between the study groups in each treatment interval.

Pair wise comparisons between groups were made by Duncan test. Significant differences in surface roughness parameters of each group between different treatment stages were assessed by repeated measure analysis of variance and LSD test.

Comparison between different treatment intervals

Figures 1 to 4 present the surface roughness parameters of the four experimental groups at different stages (initial, adhesive removal and finishing).There was no significant difference in surface irregularity between the treatment intervals when a 12-fluted TC bur was used for adhesive removal ($p>0.05$) (Fig 1). For the high speed TC bur (Fig 2), no significant difference was found for Ra and Rq parameters between treatment stages ($p>0.05$), but statistical differences were observed for Rt and Rz measurements ($p<0.05$). The repeated measure ANOVA revealed that Rt and Rz parameters were significantly lower in the initial stage compared to both the adhesive removal and finishing stages, which were not statistically different from each other. In both ultrafine diamond bur (Fig 3) and Er:YAG laser (Fig 4) groups, there were significant differences in all surface roughness measurements between the different treatment stages (p<0.01), so that the highest roughness values were found after adhesive removal and the lowest values were observed in the initial stage. The overall findings of this study implied that application of a TC bur at low-speed is the safest method regarding the damage caused to the enamel surface. The degree of irreversible enamel damage is minimal when using a TC bur at high-speed, while adhesive removal with an ultrafine diamond bur and especially by an Er:YAG laser can cause a significant and irreversible increase in the enamel surface irregularity.

Comparison between different methods of adhesive removal

The results of ANOVA demonstrated no significant difference in surface irregularity between the study groups at the initial stage (p>0.05), but significant differences were noted in the adhesive removal and finishing intervals (p<0.001). Subsequent analysis with Duncan test revealed that in both the adhesive removal (Table 1) and finishing (Table 2) stages, TC bur operated in low speed handpiece produced significantly lower surface roughness values than the diamond bur and Er:YAG laser, while ultrafine diamond bur produced a significantly less roughened surface than the Er:YAG laser (p<0.05).

The surface irregularity of teeth cleaned with the high speed TC bur was between those acheived with the low speed TC and diamond burs, showing comparable irregularity with both of these groups (Tables 1 and 2). The only exception was found in the finishing stage (Table 2), where Rt value of the diamond bur group was comparable to those of both TC bur groups. The present study investigated the efficacy of different rotary instruments and Er:YAG laser in removing adhesive residues after debonding of orthodontic brackets using contact profilometry to measure surface irregularity. Instead of evaluating experimental surfaces with a control group without intervention, surface roughness of the same teeth was measured in different treatment stages.

This method is more precise because when the comparison is made between different specimens, one could not be ensured whether surface damage has been created by the removal technique or has been present before the bonding procedure [33]. The end of the cleaning process was determined by visual examination and checking of the tooth surface with a dental explorer in order to more closely simulate clinical conditions. In agreement with most of the previous studies [11, 15, 34-36], water cooling was preferred to air cooling during the use of high speed handpiece to prevent excessive increase in intra pulpal temperature. Ra, the mathematical average of profile deviation from the mean line in a sampling depth, is usually considered as representative for enamel surface texture, but it suffers some faults, as it cannot differentiate between heights or valleys or between grooves with shallow or deep length [7]. To have a better view of surface irregularity, other roughness parameters were also measured in this in vitro experiment. When different treatment intervals were compared in each group, it was found that the application of tungsten carbide bur at low speed was the least hazardous method for enamel, because the surface irregularity was not significantly different in teeth cleaned with this bur in the three treatment intervals. After enamel clean-up with the high-speed TC bur, small increases were observed in surface roughness parameters, which were significant for Rt and Rz parameters, but not for Ra and Rq. This indicates that enamel clean up by a high-speed TC bur produces some degree of enamel damage as represented by the increased surface irregularity. Hannah and Smith [37] also emphasized that the TC bur should be used at low speed because adhesive removal at high speed would be hazardous to the adjacent enamel. The enamel surfaces cleaned by the ultra fine diamond bur and the Er:YAG laser showed severe and irreversible enamel damage which was not reversed to the pretreatment level after final pumicing. Comparison between various clean-up methods demonstrated that in general, application of tungsten carbide burs in low or high speed handpieces produced the least amount of surface irregularity. However, the surface roughness values of specimens cleaned with the high speed TC bur were also comparable to those of the diamond bur group. Actually, the numeric values of surface roughness parameters were greater in the high-speed TC bur group than the low-speed TC bur group in both the adhesive removal and finishing stages, but the differences between the two groups were not statistically significant.

These findings are in agreement with those of Zachrisson and Artun [8] who found that the most adequate results were obtained after resin removal with TC burs operated in low speed handpiece. Campbell [11] reported that the use of no. 30 fluted TC bur in high speed handpiece was the most efficient modality for removing resin remnants after debonding and produced the least amount of scarring clinically. In contrast, Gwinnett and Gorelick [6] found that the use of high speed TC bur after debonding was damaging for the enamel surface due to the creation of large pits and facets and causing significant enamel loss.

The surfaces cleaned with an ultrafine diamond bur, although acceptable compared to those cleaned with the Er:YAG laser, showed significantly greater surface irregularity than the low-speed TC bur group in both the adhesive removal and finishing stages, indicating that the use of diamond bur should not be considered acceptable for resin removal after debonding.

This finding is in agreement with those of previous studies [8, 10, 11, 14, 34]. Retief and Denys [14] reported that diamond finishing burs created grooves with superimposed abrasion marks on the resin-enamel surfaces. Campbell [11] reported that the use of diamond bur to remove adhesive remnants after debonding caused severe scarring on the enamel surface that was visible both clinically and in SEM photomicrographs. Using scanning electron micrographs, Zachrisson and Arthun [8] concluded that the use of diamond burs for finishing was unacceptable, due to the creation of devastating roughness and enamel loss. In both the adhesive removal and finishing stages, the roughest surface was obtained after enamel cleaning with the Er:YAG laser. Furthermore, it was difficult to remove the entire adhesive with the Er:YAG laser without damaging the surrounding enamel. These findings corroborate the study of Correa-Afonso et al. [29], who reported surface irregularities, a great amount of remaining restorative material and minimal inadvertent removal of healthy tooth tissue after using Er:YAG laser for removing composite restoration. Almedia et al. [32] found that the Er:YAG laser performed significantly better than the conventional technique for removing adhesive after bracket removal, but the amount of enamel ablation was considerably greater in the laser group. In the present study, Er:YAG laser was used with a pulse repetition rate of 4 Hz, pulse energy of 250 mJ and pulse duration of 350 µs (long pulse).

Pulse repetition rate has been considered as the most important parameter in determining heat accumulation in the tissue during the ablation procedure [38], encouraging the use of low pulse repetition rates to have a safe preparation [38]. Furthermore, selecting a high repetition rate necessitates the use of high water stream and this can make observation of the operating field difficult [29]. Correa-Afonso et al. [29] found that increasing the pulse repetition rate provided faster and more effective ablation of composite resin, but it caused greater removal of the healthy surrounding tissues and produced more irregularities in cavities prepared by the Er:YAG laser. In the present study, a pulse repetition rate of 4 Hz was used in order to prevent iatrogenic damage to the tooth tissue. The pulse energy of

250 mJ provided the minimum energy required for composite resin removal while minimizing the possibility of healthy tissue ablation. Hibst and Keller [31] found that the ablation rate of restorative materials depended on the pulse energy chosen and suggested energies between 250 mJ and 350 mJ necessary to achieve successful results.

Correa-Afonso et al. [29] considered a pulse energy of 250 mJ as the safest energy to prevent inadvertent removal of healthy tissues when removing composite fillings with the Er:YAG laser.

The excessive roughness observed in the laser group may be related to the ablation mechanism of Er:YAG laser which causes melted areas in the material and explodes it, subsequently pulling out the adhesive from the enamel surface. In contrast, adhesive removal with a dental handpiece occurs by wearing out the material, providing a better control of the procedure because of the more suitable tactile feedback for the clinician [29].

In the present study, final polishing with pumice failed to restore the enamel surface to the pretreatment level.

In the diamond bur and Er:YAG laser groups, pumicing caused a significant decrease in surface roughness parameters between the adhesive removal and finishing stages, but the surfaces still demonstrated statistically more irregularity compared to the initial measurement.

This finding is in agreement with those of the previous authors [8, 35] who found that final pumicing slightly smoothened the rough surfaces obtained after adhesive removal, but it could not entirely remove the deeper scratches or gouges left by different instruments. The findings of this study; however, are in contrast with those of Burapavong et al. [39], who reported that final polishing with pumice left most surfaces free of remaining adhesive and restored smoothness to the treated enamel surface. Although findings of this study advocate the use of low-speed TC bur as the safest modality for adhesive removal, SEM images in previous studies [8, 12, 40] demonstrated faint scratching and scarring after its use for enamel clean-up, suggesting that the use of this bur should also be done carefully and followed by polishing techniques in order to obtain the finest surface topography as possible.

Further development in technology is needed in the field of laser to achieve the characteristics and type of laser that can ablate the composite differentially from the tooth structure without causing tissue damage.

DISCUSSION

On the basis of the results achieved inside the limitations of this study:

1-Application of a TC bur at low speed proved to be the safest method of removing adhesive remnants after debonding of orthodontic brackets.

2-A small increase was observed in surface roughness parameters after adhesive removal by a TC bur at high speed which was significant for Rt and Rz parameters, but not for Ra and Rq measurements. Although the damage appeared to be clinically negligible, adhesive removal by a TC bur at high speed should be performed carefully.

3-Use of a very fine diamond bur or an Er:YAG laser for enamel clean up caused a significant increase in surface irregularity. Therefore, these methods cannot be advocated for adhesive removal after debonding of orthodontic brackets.

4-In comparison between groups, the application of TC burs at low- or high- speed handpieces produced the least amount of enamel roughness, while enamel clean-up by the Er:YAG laser caused the highest roughness measurements.

5-The increased roughness observed after the use of high-speed TC and diamond burs or the Er:YAG laser did not return to the pretreatment level after final pumicing, indicating an irreversible enamel damage.

ACKNOWLEDGMENTS

The authors would like to thank the research chancellor of Mashhad University of Medical Sciences for the financial support of this research [grant number 88236]. The results presented in this work have been taken from a student's thesis (No # 2450).

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